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Product-Service Systems across Life Cycle

Innovation in Product-Service System Engineering based on early customer integration and prototyping

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Abstract

Product-Service Systems (PSS) enhance product-centered offers with services and infrastructure in order to provide customer-oriented solutions. These new concepts enable companies to innovate their portfolio, thus supporting creative and adaptable solutions [1]. One of the major challenges is the integrated development of both tangible products and intangible services in respect to their interdependencies. For this reason researchers proposed a versatile set of methods and tools regarding the development of PSS. Nevertheless, two discrepancies can be stated: Firstly, prototyping has been studied inadequately in PSS research so far. For this reason *Exner* et al. proposed new approaches to fill this gap [2], including remarks to further proceed research with different degrees of technological utilization. Secondly, although customer-orientation and customer integration has been recognized as crucial for PSS, the involvement of clients or consumers in the design process is often disregarded. Consequently, this paper presents an extensive literature research regarding active customer integration and prototyping in PSS design processes. Based on these insights a concept for a new PSS prototyping approach is introduced. The method focuses on PSS concept development including the integration of the customer to evaluate and develop the concepts with intuitive touch technologies.

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Keywords: Product-Service Systems; PSS; prototyping; design; customer integration; innovation

1. Introduction

Manufacturing companies are under permanent pressure due to the need of coping with emerging trends and constantly changing customer requirements. As a result of a *acatech discussion* [3] between senior researcher in cooperation with industry four trends have been emphasized:

- Strategical development of product innovation
- Integrated product development
- Product creation as knowledge work
- Tools of product creation

The constant need of product innovation in combination with ever-shorter development cycles is in particular demanding for research and development departments. Moreover, innovations are not recognized as such by the customers due to a missing decisive added value, which leads to discussions about pseudo-innovation [4]. As a consequence customers refuse to invest in the latest state of the art. In order to valorize the portfolio, companies start to offer additional services [5]. To ensure the desired added value all PSS elements, for instance tangible products, intangible services and infrastructure, have to be developed in an integrated fashion [6]. Furthermore, the basic idea of PSS is to provide customer specific solutions instead of the classical product centered thinking [7]. Therefore, PSS research focused on the development of processes and methods which facilitate the new thinking and cope with interdependent system elements [8]. Nevertheless these diverse and international activities do not systematically comprise a milestone driven validation, for instance by means of prototyping [9]. Besides the integrated way of thinking a further representative consent is the necessity of analyzing customer needs and the specific

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environment of the PSS. However, concrete methods regarding PSS requirements analysis or active customer integration in the PSS development process are almost not discussed so far [10]. In summary research and solutions which integrate the customer, for instance with prototyping approaches, are needed. A concept which addresses these challenges is presented in this paper. The chosen research approach is discussed in chapter 2. On this basis a literature review has been conducted. The results regarding the essential research areas are analyzed in chapter 3. The new PSS prototyping and customer integration concept as well as the expected results are presented and discussed in chapter 4 and chapter 5.

2. Research approach

The study design is based on the Design Research Methodology and comprises four stages [11], see Fig. 1.

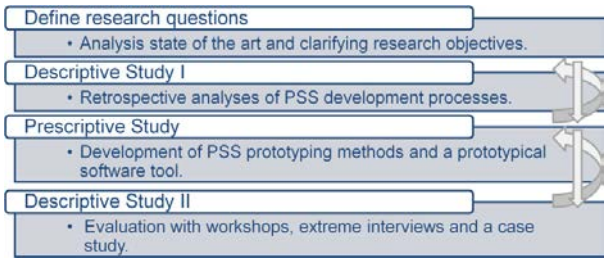

Fig. 1. Study design.

The approach emphasizes an iterative procedure between the descriptive studies and the descriptive study. The results of the literature review and research questions as well as the objectives and the design of the study are presented in chapter 3 and chapter 4.

3. Literature review

The analysis of the state of the art has been conducted on two levels. Firstly, the essential research areas: milestones, PSS development processes, prototyping and customer integration have been analyzed in order to comprise these fields of research. Secondly, a systematic literature review has been conducted in order to provide a comprehensive overview of findings for PSS prototyping approaches.

3.1. Analysis of research perspectives

In contemplation of the desired method to be developed four research areas needed to be analyzed.

In engineering design processes technical artefacts are fragmented and developed in parallel coordinated design processes [12]. From the project management perspective milestones have been proven to successful manage these complex processes [13]. At the milestone the fragmented artefact is assembled to the current design status. These approaches are known as simultaneous or concurrent engineering and are often mastered in praxis [14, 15]. Nevertheless, the coordination of each process stream as well as the specific definition of milestones is a constant challenge [16]. Especially, the vertical and horizontal linkages – that mean the temporal progression in each department as well as interdepartmentally – are difficult to manage, see Fig. 2:

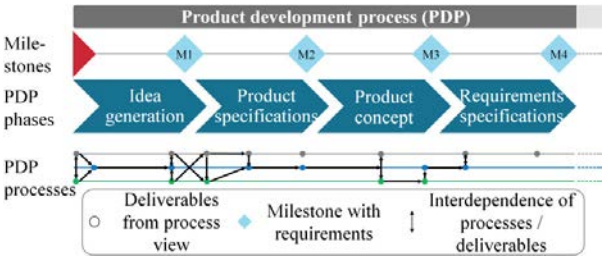

Fig. 2. Milestones and Processes in PDP.

In the service domain process models are frequently used [17]. The approaches are often based on engineering design processes [18], thus milestone thinking is also integrated. A systematic specification of these milestones and associated methods is hardly noticeable [19].

The definition of milestones becomes even more complex in PSS design processes due to the increase in diverse system elements [20]. For this reason several international research groups and expert have been developing and evaluating several PSS design approaches. A comprehensive overview can be found in *Stark* et al. [21]. It can be stated, that many of these PSS design processes focus on the concept development. On the one hand only few consider concrete activities or milestones [22, 23], yet only describing a framework instead of a detailed description or support. On the other hand methods and tools have been developed without integrating them in a PSS design methodology [2]. In conclusion, present PSS design processes do not consider milestones in a sufficient depths, thus do not possess the necessary maturity regarding decision making at milestones.

In order to enable an objective and transparent decision making, e.g. idea selection or concept approval, methods and tools are used in preparation for and at milestones. These include design reviews, mock ups, simulation etc. [2]. In the field of service engineering a variety of methods and tools are used since decades, for instance service blueprinting or quality function deployment [24, 25]. Additionally, prototyping is known and implemented across disciplines in multitude forms and dimensions in order to assess design criteria such as functionality or aesthetic [26]. Therefore, prototypes conduce as a linking element between the disciplines regarding the experimental, exploratory or evolutionary support for externalization from ideas to final solutions [27].

In respect to the design process of technical artefacts a variety of supporting prototyping methods and tools has been developed and applied [28]. The experience and penetration in practice regarding classical engineering design is high. These prototypes range from paper-based prototyping over rapid prototyping to virtual prototyping [29]. Prototyping with different degrees of fidelity – in this context the degree of

exactness – are also common in the area of service engineering. Nevertheless, they primarily focus on the visualization of the process [30]. In this regard the processes are simulated with high effort in a real environment [31]. It is for this reason that researchers started to substitute the environment, for instance an office, with digital models in Virtual Reality [32]. Nevertheless, the procedures for both approaches involve a great amount of effort.

The aspects of customer integration including the principal delimitation to business-to-business (B2B) and business-to-customer (B2C) as well manufacturer-active and customer-active has been discussed since decades [33]. Likewise, customer integration as an emphasis of customer orientation is well known and implemented in product and service engineering domains. In service engineering customer integration is characterized by a particularly strong customer contact during service delivery. Therefore, the customer is frequently involved in the service design process in order to test and evaluate the service process [30]. In engineering design processes most approaches focus on the improvement of product ideas with customer feedback. An integration in the actual design process is rarely conducted in practice [34]. In particular the virtualization of the engineering design process creates even more challenges regarding the customer integration [35]. A customer integration for PSS design processes needs to combine both approaches – the customer as innovator as well as solution improver.

3.2. PSS prototyping

The idea to develop means for conjointly prototype service and product is a new field of research. PSS prototypes which really enable an integrated testing of tangible product and intangible services have been a desideratum in research for some time. Therefore, each contribution is especially valuable. For this reason a systematic literature has been conducted using the literature database Scopus. The search term has been: "(prototype OR prototyping) AND (IPSS OR PSS OR Product-Service Systems OR IPSO OR ASC)" with a limitation to:

- the subject area "engineering"
- the years "2005-2016"
- the document types "article, conference paper, book, book chapter" and
- the languages "English, German".

The search results counted 405 hits and could be narrowed down in a two-step analysis to 14 PSS prototyping relevant contributions (see Table 1). The first analysis step is based on the information obtained from title and abstract in order to exclude non-PSS related articles. For instance "PSS" and "ASC" also conduces as abbreviations in material or biomimetic sciences. The second step complemented the procedure with a full paper analyses. The second step focused the examination to identify PSS prototyping methods which focus on integrated prototypes of tangible products and intangible service regarding the PSS design process – instead of prototypical research results. The second step is obviously subjective in determining integrated approaches.

Table 1. Relevant PSS prototyping literature based on a systematic literature review.

No.	Title	Author	Year
1	Hybrid simulators for product service-systems - Innovation potential demonstrated on urban bike mobility [36]	Beckmann-Dobrev et al.	2015
2	The role of socio-technical experiments in introducing sustainable product-service system innovations [37]	Ceschin	2015
3	Quantitative analysis of an IPS2 delivery planning approach [38]	Dorka et al.	2015
4	Validation of product-service systems in virtual reality [39]	Exner and Stark	2015
5	Product-service business concept design: Real-world case of a small furniture manufacturing firm [40]	Kim et al.	2015
6	User-integrated innovation in Sustainable LivingLabs: An experimental infrastructure for researching and developing sustainable product service systems [41]	Liedtke et al.	2015
7	Development of a strategic prototyping framework for product service systems using co-creation approach [42]	Tran and Park	2015
8	Simulation of product-service-systems piloting with agent-based models (outlined revision) [43]	Wrasse et al.	2015
9	Towards a new way of designing and managing the societal embedding of sustainable product-service system [44]	Ceschin	2014
10	Validation of Product-Service Systems - A prototyping approach [45]	Exner et al.	2014
11	Depicting product-service systems in the early phase of the product development [46]	Kammerl et al.	2014
12	Design support tools for product-service systems [47]	Kim et al.	2011
13	Product-Service Systems design process based on activities and functions [48]	Kim et al.	2010
14	Suitability of product development methods for hybrid products as bundles of classic products, software and service elements [49]	Berkovich et al.	2010

The most relevant contributions are described in the following section.

Tran and *Park* [42] developed a comprehensive PSS prototyping framework with customer integration. The methods as well as possible PSS prototypes regarding the diverse PSS elements are described, but a new development for an integrated PSS prototype is missing so far. *Liedtke* et al. [41] presented an experimental infrastructure with prototyping as a fundamental component regarding the development of sustainable PSS. Although different prototyping methods are mentioned, neither a detailed description nor a concrete PSS prototype is depicted. A further research approach by *Exner* et al. [39, 45] and Beckmann-Dobrev et al. [36] utilizes the benefits of digital models and physical prototypes and implements them in a Virtual Reality to a comprehensive PSS prototype [39]. Despite promising evaluation results the high degree of fidelity is restricting the usage, for instance regarding the integration of customers in the design process.

An important contribution which has not been found in the database search is the adaption of abstract prototyping for PSS by *Horváth* et al. [50]. However, the approach remains on a conceptual level and does not support the PSS design process with concrete solutions.

In conclusion, the advantages and benefits of prototyping in PSS design processes have not been fully exploited so far. Therefore, further PSS prototyping with different degrees of fidelity are necessary.

3.3. Research questions

Based on the analyzed research and due to additional identified challenges three research question (RQ) can be stated:

- [RQ1] Which decisions are due at which time during the PSS development process and which criteria can be defined at and between these milestones?
- [RQ2] How can prototyping approaches be utilized in order to integrate the customer in the PSS development process?
- [RQ3] Which processes and phases of the PSS development process can be supported with the new method in preparation of a milestone?

The new method needs to address and answer these questions in order to make a decisive impact in this field of research.

4. Objectives and concept

The main goal of this research is to develop a new PSS prototyping method based on a deeper understanding of decision making processes in PSS design processes. Consequently, three objectives can be derived, see Fig. 3.

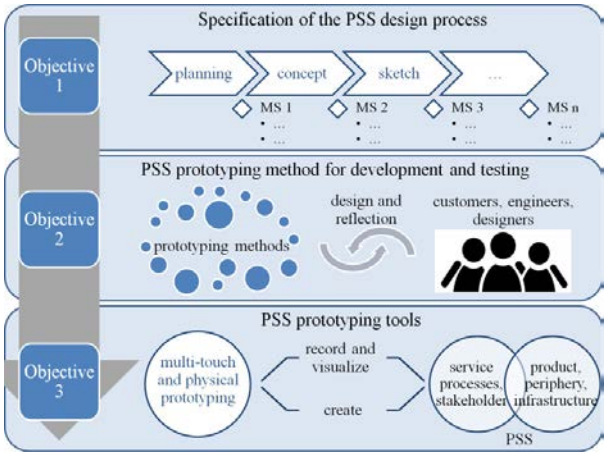

Fig. 3. Objectives.

The first objective comprises the analysis of milestones and decision making criteria in PSS design processes. For this reason PSS design processes will be analyzed retrospectively [11] regarding three completed PSS development projects. Combined with existing PSS design processes [23] the milestones in the early design phases will be defined and specified in detail, including decision criteria and available methods. The results will be evaluated in form of a workshop with both representatives of industry and research. The chosen evaluation procedure is based on a World Café [51]. Therefore, the results regarding milestones and decision criteria will be prepared for two stations in order to be discussed by the participants. The results of the discussion will be recorded for later analysis as well as immediately visualized.

The second objective comprises the development of a new PSS prototyping method. Therefore, the defined milestones are analyzed regarding their potential utilization for customer integration. The emphasis is on active and participative approaches [52], which enable a direct interaction and communication between customer, engineer and designer. For this reason, existing multi-touch technologies and prototyping approaches, especially rapid and paper-based prototyping, are tested in order to assess their capability for PSS prototyping. This combination appears to be the most promising in order to achieve a balance between low and mid fidelity concepts. This is crucial regarding successful customer integration due to the minimization of usability barriers. In this context the most suitable types of customer (e.g. lead user) will be identified. A use case will be developed in preparation of a case study and to enable a consistent and systematic testing [53]. The requirements and constraints for this use case will be defined and described in a scenario [54]. The use case focusses on a B2C urban mobility PSS. On the one hand the concept is comprehensible for the customer due to a certain acceptance and dissemination. On the other hand it is reasonable complex, thus enable a representative test case. The concept is predicted to enable a quick creation and design of PSS ideas supported by prototyping for the externalization of ideas in a mixed group of designers, engineers and customers. Additionally, a multi-touch medium enables the visualization and therefore, reflection of the idea. Altogether, the method facilitates a quick and iterative PSS design. Furthermore, the utilization of the different approaches considers the procedural character of services as well as the aesthetical character of products. The interaction is visualized in Fig. 4:

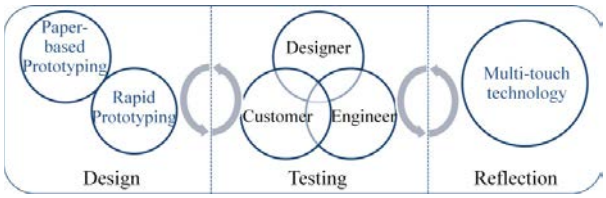

Fig. 4. PSS Prototyping concept.

First results will be prototypically tested and evaluated in a preliminary study. Therefore, the method will be supported with existing – not for this method adapted – multi-touch applications and prototyping techniques. The evaluation will be conducted with Extreme User Interviews [55], whereas the proband group consists of research experts and lay people.

This mixture enhances the probability to identify key factors for the method. Beside the optimization, the principal feasibility of the method is tested as well. Additionally, a risk analyses will be conducted in order to identify potential challenges regarding the customer integration. These risks will be contrasted with the benefits after the second study.

The third objective comprises the development of a supporting software solution. Based on the requirements derived from the first evaluation, PSS prototyping tools will be adapted in order to support the new method. The focus is on the development of a prototypical software solution, which enables an easy creation of PSS elements on a multi-touch device. Due to the simultaneous design and visualization of the PSS and with familiar technologies the inhibition threshold decreases, thus the customer can be actively integrated in the PSS design process. The final evaluation will be conducted as a case study with 24 probands of the three perspectives: engineers, customers and designers. The probands will test both, method and tool for the defined use case. Subsequently, method and tool are assessed with questionnaires regarding usability, feasibility and acceptance.

5. Conclusion and Outlook

The paper presents a new concept regarding the development of a PSS prototyping method. The concept will provide means to practicably integrate the customer in the PSS design process, thus enabling the development of creative and innovative PSS ideas and concepts. Additionally, the method will systematically support decision making processes in early design phases. The objective and research approach have been described comprehensively. Besides the development of the concept, first research steps have been conducted and presented in this paper. The main findings are comprised in a comprehensive literature review in several research areas so far. The extract of the literature review presented in this paper is complemented with findings regarding PSS design processes in research and case studies of PSS development projects in a further contribution [21].

In a next step the results of these analyses will be synthesized and evaluated, thus fulfilling the first objective and completing the descriptive study. Additionally, research in ongoing in order to analyze and utilize rapid and paper-based prototyping for PSS. Likewise multi-touch technologies are experimentally tested in order to determine the most useful ways to support sketching and reflection.

As pointed out in chapter 3 research regarding PSS prototyping is limited to only a few contributions, thus the comparability is hardly achievable. Nevertheless, first results from case studies exist and can be contrasted in order to analyze strength and weaknesses of each approach. A critical aspect refers to the reflections of risks and benefits regarding the customer integration. Additionally, a PSS prototyping synopsis should be developed and linked to s PSS design process in order to provide PSS developers with the means to utilize PSS prototyping regarding their needs.

Finally, the new method shall be easy to use and understandable for professionals in industry, researchers and lay people. The intention is to provide companies with an inspiring method and thus, help to convince people of PSS ideas and concepts.

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